

Acoustic Telemetry Survey of the Dusky Grouper (*Epinephelus marginatus*) in the Marine Reserve of Cerbère - Banyuls: Implications on the Colonization of the No Protected Areas

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The Marine Reserve of Cerbère - Banyuls, like the whole of the Marine Protected Areas (MPA) from the Western Mediterranean, represents a refuge for dusky grouper populations. Since the installation of the moratorium prohibiting its fishing in 1993, the density of population increase regularly (7 in 1985, 50 in 1988 and 193 in 2001). For a few years, the interest of scientists has been growing (observations of reproductive behaviours, density surveys) (Culioli and Quignard, 1999; Garcia-Rubies et al., 1999; Harmelin et al., 2002; Lenfant et al., 2003). However, a lack of knowledge is evident on the behaviour of the dusky grouper, in particular during the winter period. We carried out a survey by acoustic telemetry on 6 groupers between September 2005 and June 2006. This method, which allows the data acquisition of continuous detections over a long period (several months), showed (i) a strong sedentary behaviour of largest individuals (site fidelity) and (ii) a high sensitivity to variations of environmental conditions (storms).

In term of patrimonial species management like for the dusky grouper, a sedentary behaviour consolidates and encourages the conservation and the protection of the essential habitat of this species. However, it seems that a part of the population does not adopt this sedentary behaviour throughout the year. They begin to colonise sites outside the marine reserve. Regarding the status of Goliath grouper, this method can be proposed to follow populations.

KEY WORDS: *Epinephelus marginatus*, Marine Protected Areas, Acoustic Telemetry

Seguimiento Por Telemetría Acústica De Meros Comunes (*Epinephelus Marginatus*) De La Reserva Natural Marina De Cerbère – Banyuls: Implicaciones Sobre La Colonización De Zonas No Protegidas Y La Dinámica De Reproducción.

La reserva Natural Marina de Cerbère –Banyuls, al igual que el conjunto de áreas marinas protegidas (AMP) del Mediterráneo occidental, representa un verdadero refugio para una población de meros comunes. Después del establecimiento de la moratoria que prohíbe su pesca en 1993, el número de individuos contados está en aumento constante (7 en 1985, 50 en 1988 y 193 en 2001). Desde algunos años, el interés científico está en crecimiento, las observaciones de indicios de comportamiento reproductivos estivales (paradas nupciales, acoplamientos, huevos, juveniles) y los contajes se han multiplicado en las diferentes AMP (Culioli y Quignard, 1999 ; Garcia-Rubies et al., 1999 ; Harmelin et al., 2002 ; Lenfant et al., 2003). Sin embargo, poco se conoce sobre el comportamiento de los meros después del periodo de reproducción, en particular durante la fase invernal. Para llenar este vacío de datos, hemos realizado un marcaje y un seguimiento por telemetría acústica sobre 6 meros entre septiembre 2005 y junio 2006. Este método, el cual permite la adquisición de datos de detección de manera continua a lo largo de varios meses, a mostrado un fuerte sedentarismo de los individuos mas grandes al igual que una fuerte sensibilidad a las variaciones de las condiciones medioambientales. Este método a mostrado que (i) los individuos mas grandes serian particularmente mas sedentarios y que (ii) los meros presentan una gran sensibilidad a las variaciones importantes del medio ambiente (ejemplo: tempestades). Dado el estado del mero Goliath en el caribe, un estudio similar podría ser considerado.

PALABRAS CLAVES: Meros, reserva, telemetría acústica, conexión, comportamiento

INTRODUCTION

In term of conservation, the marine biodiversity and in particular the marine fish were regarded a long time more much less vulnerable than the terrestrial biodiversity (Dulvy *et al.* 2003). This perception, based on high fruitfulness of much of marine fish and their capacities to undergo important variations of densities, was deeply called in question by the collapse of several populations such as for example Atlantic Cod, *Gadus morhua* (Hutchings and Reynolds 2004). In spite of an important debate on the criteria of evaluation of their statute of conservation, it appears today clearly that the risks of extinction of populations and species relate to also marine fish (Hutchings, 2001, Hutchings and Reynolds 2004). The comparative study of Dulvy *et al.* (2003) shows indeed that the fish would not have vulnerability with the extinc-

tion lower than that of the mammals, birds or butterflies. Among the marine fish, Serranidae, which include groupers, is one of the families classified as priority by Total program the Global Marine Species Assessment (GMSA) which aims at evaluating according to the criteria of the World Union for Nature (IUCN) the state of conservation of approximately 20 000 marine species from here at 2010 (GWSG, 2007). Because of their economic weight, their distributions in all the oceans and seas tropical and moderate but also of their biological characteristics, groupers are the subject of numerous plans of conservation (GWSG, 2007). Within the Commission on the Survival of Species (SC) of the IUCN, a workgroup (Groupers and Wrasses Specialist Group) was born besides in 1998 dedicated in particular to the grouper, (www.hku.hk/ecology/GroupersWrasses/iucnsg/)

[index.htm](#)). In 2007, out of the 161 described species of groupers, only 45 were evaluated including 3 classified CE (Critically Endangered), 5 classified EN (Endangered), 13 VU (Vulnerable) and 9 NT (Near Threatened) (IUCN, 2007).

The dusky grouper, *Epinephelus marginatus* (Lowe, 1834) is an emblematic species of the Mediterranean Sea but it is also present in the Atlantic (Africa and Brazil) (Astruch *et al.* 2006). It was evaluated in 2004 and was classified “in danger of extinction” on the basis of rate important of decline of its populations (EN A2d) because of an overexploitation due in particular to its very great vulnerability with underwater hunting (IUCN 2007, GWSG, 2007, Reñones *et al.* 2007). Its biological characteristics (predator of big size, hermaphroditism protogyne, longevity) and behavioral explain this situation (Reñones *et al.* 2007). This species is single Serranidae registered with appendix III of the Convention of Bern (1995) and of the Convention of Barcelona (1995) (Sarter *et al.* 2006). In France, since 1993, the dusky grouper is partially protected by a renewable moratorium every five years (Lenfant *et al.* 2003). It is valid until December 31, 2013, date on which it will again be necessary to discuss again its renewal on the basis of scientific knowledge about French populations, in particular the dynamics of colonization starting from the Marine Protected Areas (MPA) which seem to constitute true “refuges” for the species (Astruch and Lenfant 2006). These problems explain in particular why even the demographic models simplest used in conservation biology of the terrestrial species, are very few transposed to the marine species (Wielgus *et al.* 2007). Taking into consideration these problem, the main question was: Which are the movements of the individuals inside a MPA, taking into consideration habitat available for the dusky grouper? This will make it possible to bring knowledge on the space organization of the grouper populations in the MPA presenting different level of protection (no take zone and partial reserve). Beyond the results, this study shows the interest of the use of the GIS software coupled with acoustic telemetry to answer questions of conservation of the dusky grouper and more generally of marine fish.

MATERIALS AND METHODS

Study Area

Created in 1974, The Natural Marine Reserve of Cerbère-Banyuls (France) is in the North-Western Mediterranean Sea, near the Spanish boundary. It extends on 6,5 km from linear coastal and until one thousand nautical and half towards the broad one, for an entire surface of 650 hectares (Lenfant *et al.* 2003) (Figure 1). The MPA includes two zones with different levels of protection: 65 hectares of Integral Reserve on the level of the Cape R d ris (created in 1979) and the remainder in Reserve known as “Partial” (Astruch and Lenfant 2006)

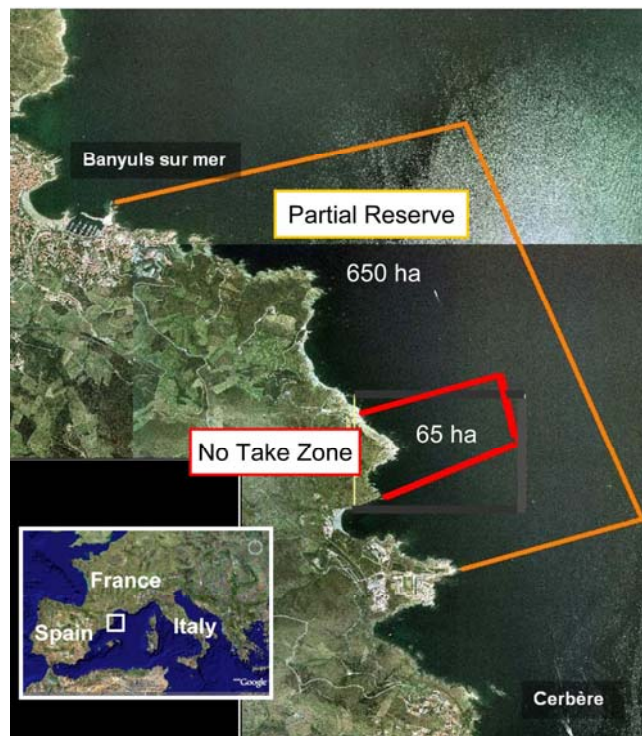


Figure 1. Study area.

(Figure 1). In the Integral Reserve or “reinforced protection zone”, only navigation (speed limited to 5 nautical miles) and the swim are authorized. In the remainder of the reserve (“Partial Reserve”), diving is authorized, as well as the commercial fishing (many authorizations limited to 12) and it amateur fishing (regulated and subjected to prior approval) (Lenfant *et al.* 2003). Underwater spear fishing is prohibited in the whole of the reserve. The site was selected for its population of dusky groupers which are only present in the MPA: from 7 individuals listed in 1985, the population passed to 202 individuals in 2006 (Bailly *et al.* 1986, Astruch *et al.* 2006). The population would be distributed for two-third in the reinforced protection zone and one-third in the partial reserve (Astruch and Lenfant 2006).

Sampling

The survey by acoustic telemetry was carried out on 6 groupers (2 males, 100 and 105 cm of total length, 4 females between 52 and 79 cm of total length) between September 2005 and September 2006 in the integral reserve by the team of the Ecole Pratique des Hautes Etudes of Perpignan (Astruch *et al.* 2006) (Table 1). After capture by anaesthesia with clove oil, each individual was equipped with a transmitter coded V13-1L (VEMCO Ltd, Nova Scotia) (emission of a signal every 30/40 seconds during one year at least) by surgical operation. This allowed an active survey by boat using a hydrophone VH110 or VH165 connected to a receiver VR100 (VEMCO Ltd, Nova Scotia) and a continuous survey by 5

Table 1. Biological characteristic of tagged individuals (total length in cm), estimated age (following Bouchereau *et al.* 1999), estimation of sex.

# Tag	Total length	Age	Sex
156	65	8	Female
157	100	17	Male
158	52	6	Female
159	75	10	Female
160	105	18	Male
161	79	11	Female

fixed receivers VR2 (VEMCO Ltd, Nova Scotia) posed on the bottom and covering the whole of the integral reserve. The active survey makes it possible to record the positions of each individual (GPS points of the boat in WGS 84 coordinates associated with a percentage of detection) whereas the continuous survey generates data of (i) presence/absence in the field of detection of the VR2 (of a ray of approximately 200 meters per beacon) and (ii) the rhythm of diurnal/nocturnal activity (Astruch *et al.* 2006).

Data analysis.

Site fidelity — i.e. the tendency of the dusky grouper follow-ups to remain or not in the integral reserve, is studied with the two types of data. Detections by the fixed receivers initially make it possible to have a general idea if the marked individuals were continuously detected or not in the integral reserve. The data of positions provided by the active surveys are treated using the “site fidelity test” of AMAE (Animal Movement Analyst Extension; Hooge *et al.* 2001) under ArcView 3.2 (ESRI Inc., Redlands CA). This makes it possible to test fidelity site, apprehended through an index of dispersion (MSD) and linearity of the movements (LI), against the null assumption of random movements per simulation of Monte Carlo (100 random trajectories) (Hooge *et al.* 2001). The MSD (Mean Squared Distances) is calculated starting from the first point (“first fix”). LI (Linear Index) is the ratio of the distance between the first and the last point of the trajectory divided by the distance covered. Only GPS points of detection higher than 60% are used in order to have a good precision for the positions of each individual.

Surfaces of habitats used — correspond to the vital domains of the individuals. They are estimated starting from the data of active survey using the nonparametric statistical method of fixed Kernel where the coefficient of smoothing H is calculated automatically by method LSCV (Least Squares Cross-Validation) (Worton 1989, Seaman

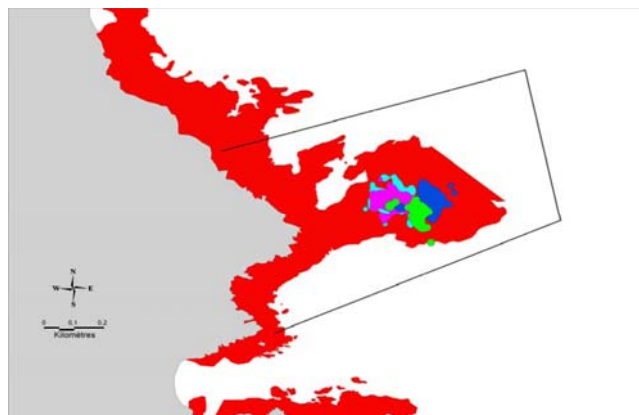


Figure 2. Cartography of vital domain (Kernel 95%) of females. Limit: No take zone - Available habitat (hard bottom): red - #156: green, #158: pink, #159: marine blue, #161: blue.

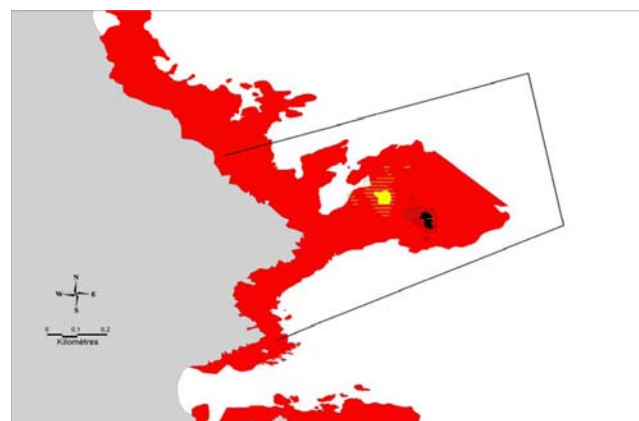


Figure 3. Cartography of vital domain (Kernel 95%: dashed - Kernel 50%: continuous color) of males. Limit: No take zone - Available habitat (hard bottom): red - #157: black, #160: yellow.

and Powell 1996). This method is based on the density of the localizations and it allots to each point space a probability of occurrence of the animal (“utilization distribution”). In this study, 95% (total vital domain) and 50% (zones of more supported activities or “core areas”) are calculated. In Kernel with 95%, the 5% of the most isolated points are not taken into account to define the contour of the vital domain (Henry 2004, Bodin 2005). Only GPS points of detection higher than 60% are used in order to have a good precision as for the positions of the individuals and to limit the space autocorrelation between the localizations. This method is implemented using AMAE (Animal Movement Analyst Extension; Hooge *et al.*, 2001) under ArcView 3.2 (ESRI Inc., Redlands CA) (Hooge *et al.* 2001).

Table 2. Mean values of MSD and LI for trajectories simulated and observed (* p<0.001, n: number of trajectories)

# Tag	trajectories	MSD mean (m ²)	LI mean
156	observed (n = 9)	1663.3 *	0.03 *
	simulated (n =100)	13220.6±7240	0.18±0.08
157	observed (n = 19)	1339.4 *	0.02 *
	simulated (n = 100)	28741.5±18271	0.13±0.07
158	observed (n = 22)	2512.9 *	0.01 *
	simulated (n = 100)	45987.6±30121	0.11±0.06
159	observed (n = 22)	2389.8 *	0.01 *
	simulated (n = 100)	74205.6±44019	0.08±0.04
160	observed (n = 17)	2445.2 *	0.02 *
	simulated (n = 100)	37522.7±23162	0.17±0.08
161	observed (n = 23)	2401.4 *	0.04 *
	simulated (n = 100)	57618.2±39289	0.12±0.06

RESULTS

Between September 2005 and September 2006, the fixed beacons collected 600,000 signals and the active survey recorded 1,476 detections (between 136 and 455 per individual) correspondent at approximately 90 hours of acquisition.

Site Fidelity

On the whole of the year of acoustic telemetry survey, the 6 dusky groupers remained in the integral reserve in a bathymetric zone ranging between 5 and 30m of depth. The fixed receivers detected all individuals for each month of the surveyed year. No individual disappeared during the survey. The indices MSD and LI observed for these six dusky groupers are all significantly weaker than those of the simulated random trajectories (Table 2). This indicates that the movements of the individuals are much more constrained than what would be awaited if the movements were random. All dusky groupers present a high site fidelity and use a quite particular zone of the habitat available.

Surfaces of Habitats Used

The intermediate size of the vital domains of the 6 dusky groupers followed is of 13,431 m² (for 95% of UD (“utilization distribution”) and of 2,077 m² (for 50% of UD) (Table 3). Dusky groupers are thus present preferentially only over 15%, on average, of their vital domain. Except for the grouper #156, females have larger vital domains (intermediate size of 14,820 m² for 95% of UD) that 2 followed males (intermediate size of 10,655 m² for 95% of UD) (Table 3). Females vital domains present overlaps (Figure 2) contrary to the 2 males which have kernels with 95% of quite distinct UD (Figure 3). Vital domains between females and males can overlap.

Table 3. Surface estimation of vital domain by fixed Kernel (LSCV), F: female, M: male.

# Tag	Sex	Number of GPS points	Kernel 95% (m ²)	Kernel 50% (m ²)
156	F	136	9459.4	1862.2
157	F	229	18533.1	1878.6
158	F	455	15326.9	2216.3
159	F	302	15961.2	2436.1
160	M	216	8127.2	1790.3
161	M	138	13182.9	2280.0

Diurnal/Nocturnal Rhythm

Individuals introduce a rather similar daily pattern over the various months of survey (from October 2005 to January 2006). The number of detection is more important during the day than during the night (Figure 4). The key phases of change of activity are the survey (8 - 9h) and the lying one of the sun (19 - 20h). Nevertheless, we observe that at certain individuals, the pattern is not also clear.

DISCUSSION

This study shows clearly that the marked individuals remained at least a whole year within the integral reserve, zone which offers the maximum level of protection in term of survival for immature and females. The vital domains of the males and the females are quite lower than the size of the integral reserve with very localized movements. During the second survey in September 2007 (always in action), these six individuals marked into 2005 were again detected on their zone of evolution (Lenfant Pers.comm.).

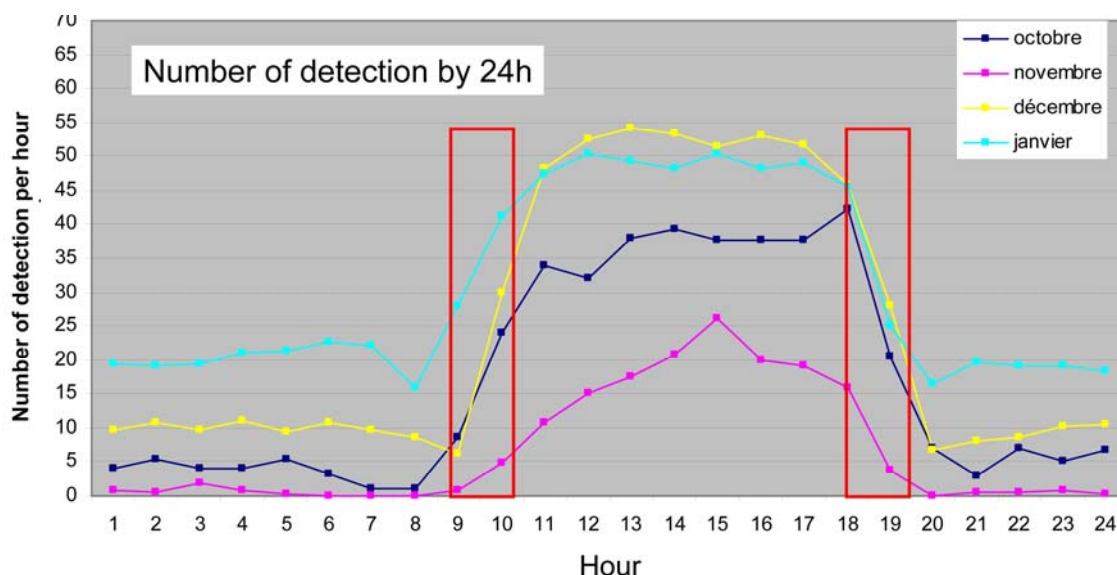


Figure 4. Number of detection per 24h over 4 month of survey (#156).

This tends to show that they remained certainly on their site well beyond the first year of the survey. These results consolidate works of Lembo *et al.* (1998) and Spedicato *et al.* (2005) for the population of the Ustica island (Sicily). Using acoustic telemetry as in this study, authors showed very strong fidelity with the site of 7 dusky groupers marked into 1997, 6 into 1998, 4 in 2001 and 3 in 2002 and this for sizes ranging between 28 and 94 cm (Lembo *et al.* 1998, Spedicato *et al.* 2005). This behavior was also raised at other species of grouper like *Mycteroperca microlepis* (Kiel 2004) and *Epinephelus itajara* (Frias-Torres 2006). These results confirm the interest of MPAs for the conservation of groupers. Indeed, it is now shown that the effectiveness of a marine reserve depends on the features of life history and the sizes of the vital domains of the species (Gerber *et al.* 2003, 2005). MPAs, which are often of small size, are tools of conservation much more effective for the species whose populations show low growth rates and restricted vital domains (Gerber *et al.* 2002). It is thus not surprising only the few populations which were maintained on the French coasts are in majority in marine reserves (Francour and Gratiot 2007).

This study is the first to use the method of estimate of the vital domains by the method of the fixed kernel in the case of the dusky grouper. Culioli and Quignard (1998) propose surfaces of territories between 1,500 and 3,800 m² on the basis of regular observation by visual census in diving of four males in Lavezzi (Corsica). This is quite lower than the results in the case of the kernels with 95% of UD but corresponds completely to the kernels to 50% of UD. That can be explained by the many difficulties to follow the movements of the individuals in diving, this one not making it possible to delimit precisely zones most frequently used. Acoustic telemetry seems a technique

much more informative for the study of the dusky grouper (Lembo *et al.* 1998, Spedicato *et al.* 2005). This technique remains however very expensive and requires the tagging of individuals what is very problematic in the case of dusky grouper due to its low catch ability and statute of protection. These two points explain the reduced number individuals followed in this study. We stay very careful in the interpretation of the results. As we tag individuals after the reproduction to limit disturbances, it is very probable that part of the population stay always in this zone (Astruch *et al.* 2006). The next tagging campaign should rather be carried out with the whole beginning of the summer in order to take account of this problem.

These six individuals of very different sizes are, however, at least representative of part of the population of the Natural Marine Reserve of Cerbère-Banyuls. It as should be noted as the other studies are confronted with this same problem of weakness of the sample size but that the convergence of the results reinforces their relevance (Lembo *et al.* 1998, Spedicato *et al.* 2005). The dusky grouper population seems made up very sedentary individuals at least over a period of a few years. Although the method of fixed Kernel is recognized as having the advantage of being not very dependent on the number of points, Seaman *et al.* (1999) recommend to have at least thirty independent localizations, which is largely respected in this study. Moreover, GPS points used follow the criterion of independence (i.e. the absence of space autocorrelation) of White and Garrott (1990). Authors consider that two localizations are independent if the time which separates them is higher than the time put by the individual to cross its vital domain. To the weakness of the number of followed individuals the precision of the estimates of the vital domains is thus opposed.

The number of detection recording continuously made it possible to analyze the evolution of the daily behavior of the 6 dusky groupers on a cycle of 24 hours. The fact that the number of detection is more important during the day than during the night can be interpreted like an increase in activity during the day. Some change in daily pattern activities could be related to the distance separating the individuals from the fixed receiver. Individuals living near the receiver have a pattern much more clear than those living distant. The distance being a factor of loss of signals, this could partly explain the strongest variability of many detection received by fixed receivers.

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